

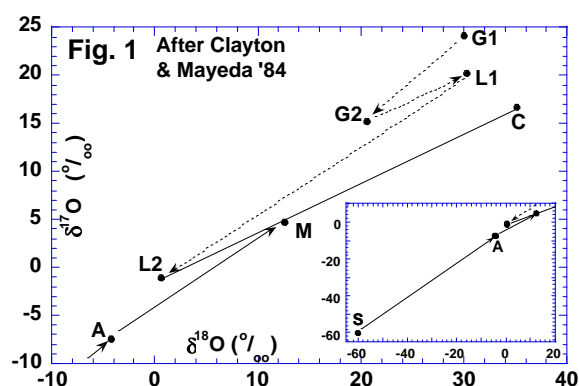
Solar Oxygen Isotope Predictions: Theme and Variations R. C. Wiens^{1,2}, D. S. Burnett¹, and G. R. Huss¹, ¹Geological & Planetary Sciences, CalTech, Pasadena, CA 91125; wiens@gps.caltech.edu, ²Present address: Los Alamos National Laboratory, M/S D466/NIS-1, Los Alamos, NM 87545.

Overview. The average composition of the solar nebula is widely believed to be preserved in the outer layers of the Sun. The solar O isotopic composition is presently unknown, but would be measured to 1 ‰ by the proposed Genesis mission. There is no obvious correlation between solar system oxygen isotope variations and compositions observed a) nearby in the galaxy [compiled in 1] or in b) acid-resistant interstellar grains found in meteorites [1]. Although there are several possible theories [e.g. 2,3,4] attempting to explain solar system O isotopic heterogeneities, only the 2-component gas-solid mixing theory [e.g. 2] allows specific predictions for the solar composition. Here we discuss those predictions and several possible variations.

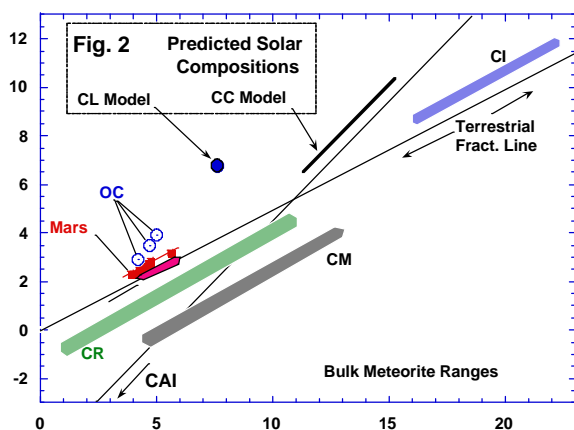
Predictions. Clayton and co-workers have provided two distinct models for predicting the solar O composition: one model [e.g., 2] assumes that gas and solid components were in equilibrium for the Carlisle Lakes chondritic meteorites, which have the highest $\Delta^{17}\text{O}$ composition, approximately $(\delta^{18}\text{O}, \delta^{17}\text{O}) = (6,6)\text{‰}$ rel. SMOW [5]. Gas-solid equilibrium fractionation is $\sim (2.0, 1.0)$ at temperatures where equilibration can occur [6,7]. From the overabundance of O relative to rock-forming elements [8], one can assume $\sim 79\%$ of O now in the Sun is from nebular gas and 21% was from nebular dust (this model is relatively insensitive to this assumption), leading to a solar “CL” prediction of (7.6, 6.8) shown in Fig. 2.

A second prediction (“CC”) is based on the apparent equilibration sequence in carbonaceous chondrites [9], shown in Fig. 1, assuming the simplest 2-component model. The lowest value measured in CAIs--presently $\sim (-60, -60)$ [e.g., 10]--defines the solid component initial composition “S” (Fig. 1 inset). Partial equilibration produces CM and CI anhydrous phases “A”, which react with water condensed

from the gas phase to produce phyllosilicate matrix “M”. The composition of calcite “C” (CM) or magnetite (CI [11,12]) determines the final water composition “L2”. The initial water composition, “L1”, present before water-rock interaction, can be determined from the inferred water/rock ratio and the length of the A-M shift. The L1 water is assumed to have condensed from gas of composition “G2”. Finally, the initial nebular gas composition “G1” can be estimated by the shift in solids from initial composition S to anhydrous minerals A and from the assumed (21/79) solid/gas ratio. From these estimates [9], a solar composition in the range of (11.2, 6.5) to (15.4, 10.5) is predicted, as shown by the “CC model” line in Fig. 2. The lower end of this line differs from the CL prediction by $\delta^{18}\text{O} \geq 3.6\text{‰}$, highlighting the more widespread issue that many chondritic materials are significantly lower in $\delta^{18}\text{O}$ than predicted by extension of the CAI line, even after accounting for gas-solid equilibration.

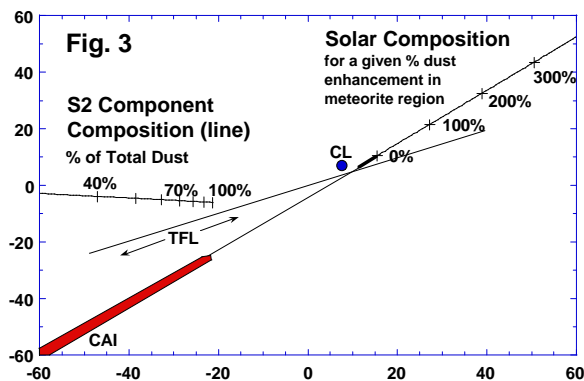


Variations. It would be helpful to know how sensitive these predictions are to processes that may have been at work in the early solar system to determine 1) to what extent O isotopes can constrain early solar system processes, and 2) whether a solar O composition differing from predictions invalidates the theory. Below we discuss a couple of variations on the models.

SOLAR OXYGEN ISOTOPIC PREDICTIONS: Wiens *et al.*

1. Additional dust component(s).

The strongest argument for only two components comes from the fact that the CAI materials lie on a relatively tight line. Because it is based on partially equilibrated material rather than initial end-members, the CC solar O prediction is insensitive to additional dust components contemporaneous with CAI material if they were also present in materials A and M (Fig. 2). However, additional component(s) may exist which did not participate in CC dust-gas mixing. A relatively ^{18}O -poor dust component present in ordinary chondrites and the Sun, but missing from the carbonaceous chondrite matrix material, might reconcile the CL and CC solar predictions. If CL compositions are produced by addition of a new "S2" dust component to the CAI + gas mixture, the S2 component would need to either have a significantly different isotopic composition or else comprise a large fraction of the total dust. Fig. 3, left side, indicates dust compositions if this component were 40, 50,...100% of the dust fraction in CL meteorites, using the gas reservoir composition corresponding to the lower end of the CC model prediction in Fig. 2. Using the gas reservoir corresponding to the upper end of the prediction results in S2 component compositions roughly coincident with extension of the terrestrial fractionation line (TFL). Interestingly, these compositions are consistent with the bulk of group-3 presolar oxide grains [1]. In this scenario, the solar O composition would lie between the CL and OC predictions, as the Sun would presumably have inputs from both independent dust reservoirs.



2. A Non-solar Dust/Gas Ratio in the

meteorite dust/gas equilibration region would allow significantly different solar compositions than predicted by either the standard CL or CC models. Many solar system models [e.g. 13] invoke local dust enrichment factors of an order of magnitude or more. Fig. 3, upper right, shows the predicted solar values for given meteorite dust/gas enrichment factors up to 300%. Dust enrichment alters the water/rock ratio calculated for carbonaceous chondrite matrix material, but not too significantly for the modest enrichments shown in Fig. 3.

Summary. The solar oxygen isotopic compositions predicted by the Clayton *et al.* models are shown in Fig. 2. If the difference between the CL and CC predictions is due to an additional dust component, the solar value may lie in the triangle between the CL point and the CC line. However, if the dust/gas ratio in the CC equilibration region is higher than the nebula average, heavier solar compositions are predicted (Fig. 3). The solar O value will clearly enhance our understanding of the solar nebula.

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